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Tailoring ZSM-5 zeolites for the fast pyrolysis of biomass to aromatic hydrocarbons

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Catalytic fast pyrolysis (CFP) represents a sustainable method to convert raw biomass from different sources into useful chemicals and fuels in a single step. ZSM-5 zeolite has been identified as the best catalyst for this reaction. Its pore structure provides unique shape selectivity toward C_6-C_{11} aromatics—in particular to benzene, toluene, xylenes—which are important building blocks for the chemical industry. However, the exact role and impact of catalyst features such as crystallinity, elemental composition, porosity, and acidity on the catalyst's performance remain elusive. The interplay of these parameters under reaction conditions represents a major roadblock that has hampered significant improvement in catalyst design for over a decade.

Here, we studied commercial and laboratory synthesized ZSM-5 zeolites and combined data from ten complementary characterization techniques in an attempt to identify parameters common to high-performance catalysts. We show that crystallinity and framework aluminum sites accessibility are critical to achieve high aromatic yields. In contrast, mesoporosity which was expected to enhance intra-crystalline diffusion played only a minor role. These findings enabled us to synthesize a ZSM-5 catalyst with enhanced activity, offering the highest aromatic hydrocarbon yield reported to date.